Cooperative Extension NRAES–99

Silage: Field to Feedbunk

Proceedings from the
Silage: Field to Feedbunk
North American Conference
Hershey, Pennsylvania
February 11–13, 1997

Northeast Regional Agricultural Engineering Service
Cooperative Extension
152 Riley-Robb Hall
Ithaca, New York 14853-5701

★ Errata Sheet ★

NRAES–99
Silage: Field to Feedbunk

Proceedings from the
Silage: Field to Feedbunk
North American Conference
Hershey, Pennsylvania
February 11–13, 1997

1. In the paper entitled "Animal Response to Silage Additives," by Limin Kung, Jr. and Richard E. Muck, on pages 200–210, note the following correction.

   On page 202, in table 2, the number of studies with positive intake responses to enzymes currently reads 2%.

   The correct percentage is 21%.

Animal Response to Silage Additives

Limin Kung, Jr., Ph.D.
Associate Professor • Department of Animal and Food Sciences
University of Delaware • Newark, Delaware 19717-1303

Richard E. Muck, Ph.D.
Agricultural Engineer • USDA, Agricultural Research Service
U.S. Dairy Forage Research Center • 1925 Linden Drive West
Madison, Wisconsin 53706

— Limin Kung's speaker biography appears on page 432 —

Introduction

The previous paper by Muck and Kung summarized how various additives have affected the ensiling process and silage quality. In addition to these effects, feeding treated silages has also improved animal performance in a variety of ways. Some of the common indices used to measure animal performance include dry matter (DM) intake, milk production and(or) milk composition, body weight gain and(or) condition, nutrient digestion, and conversion of nutrients to milk or body weight. Unfortunately, it is not always clear how treating silages with additives results in improvements in such measurements. As an example, reasons why additives that inhibit silage acid production or directly improve nutrient digestion cause increased weight gain in cattle can be easily rationalized but it is more difficult to understand how cows produce more milk if the composition of the treated silage is virtually unchanged. Some effects of silage additives and possible reasons for improved animal performance are listed in Table 1.

This review will concentrate on documenting animal responses to consuming silages treated with additives and explaining the possible reasons for such responses. Only the commonly used silage additives in North America will be reviewed; i.e. microbial inoculants, enzymes, propionic acid and non-protein nitrogen (NPN) additives.

Table 1. Effects of silage additives on fermentation and possible reasons for improved animal performance.

Effect(s) of Silage Additive	Reason(s) for Effect(s)	Results and Possible Effects on Animal Performance
More rapid drop in pH; lower pH	Dominance of homofermentative lactic acid bacteria	Inhibition of undesirable microbes; improved protein preservation and nitrogen metabolism
Inhibition of fermentation; e.g. high levels of acid addition or other fermentation inhibitors	Inhibition of microbial growth	Improved intake due to a reduction in overall fermentation end-products and reduced acidity
Greater lactic acid:VFA ratio, lower acetic acid concentration	Dominance of homofermentative lactic acid bacteria	Lower acetate may result in increased DM intake, improved rumen microbial fermentation and palatability
Increased propionate concentration	Due to direct addition or microbial production	Improved aerobic stability leading to less spoilage and potentially better intake; less mycotoxin formation
Lower butyric acid	Lower pH leads to inhibition of clostridia	High levels of butyric acid are an indicator of clostridial fermentation which is accompanied by high degree of protein degradation, amine formation and possible clostridial toxin formation; improved intake with low levels of butyric acid
Lower ammonia N and less free amino acids; lower concentration of amines	Dominance of homofermentative lactic acid bacteria causing a rapid drop in pH inhibits plant proteases	Less soluble protein, less free amino acids leading to improved nitrogen metabolism; improved intake
Greater concentration of peptides	More rapid drop in pH; dominance of homofermentative lactic acid bacteria	Peptides may stimulate microbial protein production
Lower concentration of ethanol	Inhibition of yeasts which are primarily responsible for aerobic spoilage	Improved aerobic stability and lower ethanol may improve intake
Lower fiber content	Partial digestion of fiber by enzymes	Potentially greater nutrient utilization
Increased water soluble carbohydrates	Partial digestion of fiber by enzymes	Potential for worsened aerobic stability; decreased intake
Improved nutrient digestion; e.g. fiber or starch	Partial digestion of fiber by enzymes; unknown effects by lactic acid bacteria	Change in physical or chemical structure of fiber; greater nutrient/energy utilization; faster rate of digestion; greater intake
Improved aerobic stability (less heating and molding)	Inhibition of yeasts which are primarily responsible for aerobic spoilage	No mycotoxins, potential for improved nutrient intake
Inhibition of undesirable microorganisms	Low pH, competition from inoculant microbes, production or addition of other inhibitory substances	See effects from yeasts and clostridia
Increase in lactic acid bacteria	From added inoculant	Probiotic effect or other unknown effects (e.g. bacteriocins) resulting in improved intake or feed conversion.
Change in unidentified products	Unknown	Unknown effects resulting in improved intake or feed conversion

Microbial Inoculants

As recent as 5-10 years ago, many questioned the efficacy of microbial inoculants for silages. Controversies existed about items such as strain selection, stability of the microorganisms and inoculation rates. Since that time, improvements have been and are being made in these areas and there is ample evidence documenting positive responses in animal performance from treated silages. In our current review (Table 2) of literature (1990-95) we found positive responses to microbial inoculants in intake (28% of studies), gain (53% of studies), and milk production (47% of studies). These averages have slightly improved from those reported in a 1985-92 summary of inoculant studies where the response to intake, gain and milk production were about 25, 25, and 40% of the time. The average response in milk production was a +3.03 lb/d in studies where milk production was enhanced in the 1990-95 summary. Other summaries have also shown positive effects to microbial inoculation. In an earlier summary from a single research location, Bolsen et al. (1992) reported feed efficiency was improved by 1.8% and animals gained 3.6 more pounds of body weight per ton of crop ensiled.

Table 2. A summary of animal responses to microbial inoculants between 1990 and 1995.

	Intake		Gain		Milk Production	
Type of Study	Inoculant	Enzyme	Inoculant	Enzyme	Inoculant	Enzyme
Number of Studies	67	29	15	10	36	12
Studies with Positive Responses	28%	2%	53%	40%	47%	33%

Although the results of the current summary are encouraging, some caution should be used when interpreting such data because all inoculants are not the same and the conditions (e.g. rate of application, crop, moisture levels) varied markedly among the studies. As many have pointed out in the past, products with organisms with the same name are not necessarily the same organism and may not have the same effectiveness. Thus we have tried to find data relative to specific inoculants of specific manufacturers of inoculants. Specifically, an impressive number of animal experiments has been conducted using a single silage inoculant containing *Lactobacillus plantarum* MTD1. A summary of 14 lactation studies conducted in University and government research institutes in North America and Europe using MTD1 is shown in Table 3 (Owen and Moran, 1993). Statistical analyses revealed that DM intake was numerically increased by 1.1 lb/d (+ 4.8%) and that milk production was significantly increased by 2.6 lb/d (4.6% increase). Improvements in milk yield were obtained with a variety of crops (grass, corn, alfalfa) across a wide spectrum of dry matter contents (15 to 46% DM). Body weight gain also tended to be better in cows fed silage treated with MTD1 (0.20 versus 0.40 lb/d).

Table 3. The effect of feeding silage inoculated with MTD1 on silage DM intake and milk yield from lactating cows.

	Silage DM Intake, (lb/d) CONTROL	Silage DM Intake, (lb/d) MTD1	Milk Yield, (lb/d) CONTROL	Milk Yield, (lb/d) MTD1
Average	23.1	24.2	57.2	59.8
Difference		+ 4.8%		+ 4.6%

Similarly, 19 comparisons with MTD1 were summarized by Moran and Owen (1995) for beef cattle (Table 4). Across all studies and types of forage, cattle fed inoculated silage ate 7.5% more DM and gained 11.1% more weight.

Table 4. The effect of feeding silage inoculated with MTD1 on silage dry matter intake and average daily gains in cattle.

	Growing Cattle				Finishing Cattle	
	Grass Silage (n = 5)		Alfalfa and Corn Silage (n = 5)		Grass Silage (n = 9)	
	Silage DM Intake, lb/d	Average Daily Gain, lb/d	Silage DM Intake, lb/d	Average Daily Gain, lb/d	Silage DM Intake, lb/d	Average Daily Gain, lb/d
Control	9.92	1.45	16.04	2.33	14.50	1.12
MTD1	10.45	1.67	17.97	2.55	15.05	1.23
Difference	+ 5.3%	+ 15.2	+ 12.0	+ 9.4	+ 3.8	+ 9.8
P value	NS	< 0.01	< 0.10	< 0.01	NS	< 0.01

Other specific inoculants have also been effective in improving animal performance. For example, we found data from 5 lactation studies using microbial inoculants from a manufacturer in the US which resulted in an increase in milk production of 1.8 lb/d. Another inoculant from a different US manufacturer resulted in an increase in average daily gain of 11.9% in 4 studies with beef cattle. In Europe, that same manufacturer recently submitted data from studies with an inoculant specifically designed for grass silage and reported an increase in weight gain from 9 beef studies of 9.6% and increase in milk yield of 3.1% from 8 dairy studies (Thaysen, 1996).

Considerable effort has been devoted to understanding how inoculants affect animal performance (See various effects in Table 1) since such improvements are in many cases the principal economic justification for inoculant use (in addition to improved nutrient recovery and enhanced aerobic stability). Improvements in DM digestion are closely linked to enhanced animal performance. In our current literature review (1990-95) animal performance was improved in one aspect, at least, in 9 of 13 times when DM digestion was improved; but only 5 of 14 times when DM digestion was not affected.

However, it is more difficult to explain how shifting lactic acid bacteria fermentation to homofermentative pathways should improve rumen fermentation in the animal and possibly have some positive effect on palatability. In fact, in some studies animal performance has been enhanced although commonly measured indices of silage fermentation were not affected (e.g. Kung et al., 1993). Such findings suggest that we are not measuring all the appropriate indices of silage fermentation. For example, Weinberg and Muck (1996) suggested that silage microbial inoculants may provide a probiotic effect by inhibiting detrimental microorganisms in the silage and rumen or by producing beneficial substances which may promote specific rumen microbial populations which could lead to enhanced animal performance. A probiotic can be defined as a culture of microbes, which when fed to the animal beneficially affects the host by improving the properties of the original gut microflora. Others have suggested that more work on measurements such as near infra-red and other spectral analyses may identify other indices responsible for improvements in animal performance. Hypothetical evidence which supports the possibility of a probiotic or other unmeasured effect on animal performance was reported by Rooke and Kafilzadeh (1994) where the silage inoculant MTD1 and 2 other lactic acid bacteria-based inoculants improved silage fermentation but animal performance was only enhanced by the former.

Enzyme Additives

Enzymes have been used as silage additives for several years and have had variable effects (see various effects in Table 1) on silage fermentation (previous review by Muck and Kung). Most products have been based primarily on enzymes capable of degrading the plant cell wall or fiber (e.g. cellulases, xylanases, pectinases) but some have contained amylases (starch degrading enzymes) as well. Remember that enzymes are usually a "complex" of proteins with hydrolytic activity. In addition, enzymes with the same name may possess highly different activities As with microbial inoculants some caution must be taken in summarizing broad sets of enzyme data because of a lack of uniformity among studies relative to substrate, treatment conditions, crop, and activity, source and specificity of the enzymes. Moreover enzymes were often added with microbial inoculants in many of the studies reviewed. In general, there have been fewer studies on silages treated with enzymes than with silages treated with microbial inoculants. Effects on subsequent animal performance have also been less than found with inoculants. In our current review of the literature (1990-1995), enzyme treatment resulted in positive effects on intake 21% (n = 29), gain 40% (n = 10), milk production 33% (n = 12), and feed efficiency 27% (n = 11) of the time (Table 2). These results differ slightly from a 1985-92 summary where intake, gain and milk production were improved only about 25% of the time (Muck, 1993). The average increase in milk production was 2.00 lb/d in studies where milk production was enhanced in the current (1990-95) summary. Improvements in DM digestion were only positive 9% of the time (n = 78) which leaves much speculation as to how enzyme treatment results in improved animal performance.

Recently, there has been renewed interest in treating feeds with enzymes just prior to feeding. Excellent reviews were recently published by Beauchemin et al. (1996) and Treacher and Hunt (1996). This method of treatment provides increased flexibility and also bypasses any negative interactions that the ensiling process may have on silage enzyme performance. Proteolytic activity from the plant, considerable microbial metabolism, interactions with moisture content and rapid production of acids results in a harsh environment that may not be optimal for enzyme activity during ensiling. Obviously, treating silages with enzymes just prior to feeding (rather than at the time of ensiling) does nothing to improve silage fermentation but it can improve the nutritive value of silage. In general, the enzymes have possessed fibrolytic activity (e.g., cellulases and xylanases). Enzyme preparations sprayed onto forages prior to feeding have improved in vitro (Hirstov et al., 1996) and in vivo (Lewis et al., 1996) digestion. Spraying fibrolytic enzymes onto alfalfa silage before feeding increased intake by 8.7% and tended to improve body weight gains in steers (Michal et al., 1996). Several reports have also documented improvements in lactational performance. Lewis et al. (1995) sprayed a mixture of fibrolytic enzymes onto the forage portion of a total mixed ration that resulted in cows consuming 4.4 lb more DM per day and producing 2.9 lb more milk per day. Stokes and Zheng (1995) also reported that spraying enzymes on the forage increased DM intake by 10.7% and milk yield by 14.7%. Our lab (Kung et al., 1995, 1996, unpublished data) has also obtained positive responses to treating the forage portion (primarily corn silage) of a total mixed ration with enzymes in two consecutive years. To date, the largest increase in milk production due to enzyme treatment was reported by Sanchez et al. (1996) where cows fed a total mixed ration whose forage was treated with a moderate level of enzyme produced 13.9 lb or 15.9% more milk than did control cows. A considerable amount of work is still required before commercial products will be available to the producer. Optimizing the final enzyme application rates will be crucial since there have been indications of reduced performance with high levels of enzyme treatment. Sources of enzyme, cost benefit ratio, and specificity of enzymes for a particular forage and enzyme activities will also be important in the success of final commercial formulations.

Non-Protein Nitrogen (NPN) Silage Additives

Various NPN additives such as urea, anhydrous ammonia, water- or molasses-ammonia mixes have been added to forages at the time of ensiling. The main goals of NPN additions are to increase the crude protein content (urea or ammonia) of a silage and improve aerobic stability or bunk life (primarily ammonia).

Increasing the crude protein content would not be expected to affect an animal's utilization of a silage within properly formulated rations. Thus the benefit would be one of economics relative to cost of a crude protein equivalent. Improved aerobic stability could improve intake if the untreated silage were heating at the time of feeding and the treated silage was not. Consequently, these two factors alone suggest that NPN additives would not consistently improve animal performance.

However, ammonia does affect the plant in ways which would be expected to improve animal performance more consistently. Ammonia can break some of the linkages between hemicellulose and other parts of the plant cell wall. This would be expected to improve both DM and fiber digestibility. In our current survey (1990-1995), DM and fiber digestion were improved in 39 and 13% of the cases, respectively. In a previous review (Muck, 1993), DM and fiber digestion were affected more consistently (84 and 100%, respectively). The reasons for the discrepancies between studies in the 1980's vs. 1990's are not known, but clearly both ammonia and urea can improve silage digestibility.

A second area where ammonia may improve silage utilization is by preserving true protein during ensiling. There is evidence in both the current and previous reviews that true protein levels are higher in NPN-treated silages. Presumably, the ammonia is either inactivating the proteolytic enzymes that break down protein or the increase in silage pH at the start of ensiling is reducing enzyme activity. In our current survey, six trials (3 with ammonia, 3 with urea) measured N retention by ruminants fed NPN-treated silages. In all three ammonia trials and in one of the urea trials, N retention improved, indicating the preservation of protein in the silage did lead to improved N utilization by the animal.

Our current (1990-95) survey found only three studies with ammonia-treated silage that reported any measure of animal performance other than intake. In those three, gain was improved in one of two trials and milk production was unaffected in one trial. Intake was increased in 5 trials, reduced in 5 and unaffected in 7 by use of NPN additives. There were no strong trends relative to type of crop ensiled or form of NPN used although corn silage intake was not reduced in any trial and alfalfa silage intake was not improved.

An earlier review by Ely (1978) of NPN treatment of corn silage found that urea treatment at ensiling provided small but consistent improvements in gain, milk production and feed efficiency relative to adding urea to the silage at the time of feeding. In contrast, ammonia was more variable in its effect on animal performance with a number of negative effects. In our current survey however, urea was as likely to produce a negative effect on intake as ammonia.

The inconsistencies of animal response to NPN treatment are not always easily explained. With alfalfa and high quality grass silages, NPN treatment has increased the risk of a clostridial fermentation, which typically will reduce intake, and most likely explains some negative results. In such high crude protein crops, NPN treatment does make sense because additional NPN is not needed nutritionally and may cause undesired reproductive problems in dairy cattle. With corn and sorghum silages, the occasional negative response may reflect an inability to apply the product uniformly at the desired rate or the effects of additional fermentation negating the improvements in digestibility provided by NPN treatment. With these silages, NPN treatment can be beneficial in upgrading crude protein content and improving bunk life provided that care is taken to apply the product uniformly and over application is avoided.

Propionic Acid-Based Silage Additives

Various chemical preservatives have been used to enhance the aerobic stability of silages. Of the short chain fatty acids, propionic acid has the greatest antimycotic activity (Woolford, 1975). In recent years (1990 to 1995) there have been few studies reporting on the effect of feeding propionic acid treated silages on animal performance. In older literature, high levels of propionic acid (> 1.0% on a DM basis) were added to silages resulting in restricted fermentations and improved DM intakes (Mann and McDonald, 1976; Huber and Soejono, 1977). Leaver (1975) conducted studies where propionic acid was added to corn silage at 1.5%, of the DM during ensiling. Newer commercial formulations often contain combinations of organic acids and other active ingredients and have lower suggested application rates (usually less than 1%). For example, Kung et al. (1996) added several propionic acid-based additives to corn silage at rates of 0.2% to 0.3% of the DM. These low rates improved aerobic stability and had minimal effect on silage fermentation.

Optimally, producers should manage their silage harvesting and feeding practices to minimize the potential for aerobic spoilage in the feed bunk. However, in difficult situations, there has been some interest in treating silages or TMR with propionic acid-based preservatives just prior to feeding to retard aerobic spoilage. Such applications have no effect on silage fermentation but they can affect silage quality during exposure to air and thus this management technique warrants some discussion. There are limited data in this area but Kung et al. (1996) reported that addition of a propionic acid-based preservative to a 60% silage-based TMR reduced the increase in pH, temperature and numbers of yeast associated with aerobic spoilage when compared to an untreated TMR. However, animal performance was not affected in mid- to late-lactation cows. More information in this area is needed to document negative effects of aerobically spoiled silage resulting in reduced animal performance. In addition, propionic acid-based preservatives are still costly and cost benefit assessments are needed.

Assessing Silage Quality and Using Additives

Muck and Kung (see previous paper) have reviewed how silage additives affect fermentation (e.g., acid concentration, ethanol production, changes in nitrogen fractions, and changes in microbial populations). Unfortunately, most silage fermentation end-products (with possibly the exception of soluble nitrogen and ammonia N) are not normal components of feed analyses. Because of this, the producer has very little knowledge relative to silage quality other than protein and fiber content. For example, one could have harvested alfalfa silage in the bud stage of maturity with high protein and desirable fiber content but have an undesirable silage fermentation. A logical question then is: "How can a producer judge the quality of his silage fermentation and what steps can she/he take to potentially compensate for poor quality silage and where do silage additives play a role?" Unfortunately, there are no readily available laboratory analyses that relate changes in silage fermentation end-products with animal performance. However, one of the easiest things that can be done is a visual and smell assessment of the silage. Good quality silage looks normal (light green to green-brown) and smells like lactic acid (similar to sour milk). Silage that smells rancid fishy and(or) putrid, is slimy, and looks brown to yellowish green may have undergone clostridial fermentation. As a result intakes may be lower and protein nitrogen definitely will have been adversely affected. In this situation the producer may compensate by limiting use of this silage, supplementing with better quality forage, increasing the concentrate to compensate for a reduction in energy value of the silage, and increasing the amount of rumen undegradable protein and/or amino acids. If botulism poisoning is also suspected, cows can be vaccinated against the toxins but this is a very expensive treatment. For the next season, the producer should consider wilting to a higher DM content (> 30% DM) and/or use of a microbial inoculant to avoid clostridial growth.

In particular reference to corn silage, a strong smell of alcohol is an indicator of metabolic activities by spoilage yeasts. Such silage usually has the potential to heat rapidly in the silo or feed bunk. Although not adequately documented, silage undergoing extensive aerobic deterioration probably leads to a depression in DM intake. In this situation, removal rate of the silage from the silo should be assessed to keep heating to a minimum. Use of a bunk or TMR preservative (usually propionic acid-based product added to the feed prior to feeding) may also be warranted. For the next season, use of a microbial inoculant or propionic acid-based preservative may be warranted.

Silage that is dark, black and smells like burnt sugar or tobacco has undergone a high degree of heating. Extreme heating is usually a result of silage that has been packed too slowly, too loosely, has been exposed to air and(or) is too dry. If the silage has already been heat damaged, the energy content is reduced and nitrogen fractions damaged. In addition to minimizing use of this silage, increased concentrate, increased protein, and an overall reassessment of nitrogen degradability could be partial solutions. In the next season, the producer should consider monitoring moisture level to ensure optimum harvest conditions, filling silos rapidly, and using a silage inoculant or other additive that has been designed to improve aerobic stability.

Summary and Conclusions

Silage additives are not substitutes for good management. Of the common additives used in North America, there is ample evidence in the literature that microbial inoculation can improve silage fermentation and animal performance. The results for enzymes added at ensiling are less conclusive. In its place, there has been much interest in treating silages with enzymes just prior to feeding. Initial studies look promising but more research is needed. Although there appears to be some renewed interest in propionic acid-based preservatives, there is limited data relative to improved animal performance. Use of non-protein nitrogen additives has been somewhat controversial but their use is limited.

A producer needs to decide which type of additive meets his or her goals. In picking a specific product within a type, he/she should ask for information about a product's effectiveness. Data which documents improvements in silage fermentation should be reviewed. In addition, data with the specific additive should be available which documents positive effects on animal performance if that is also being claimed. Products or product lines with large data bases on improved animal performance may be more credible.

References

Bolsen, K.K., R.N. Sonon, B. Dalke, R. Pope, J.G. Riley, and A. Laytimi. 1992. Evaluation of inoculant and NPN silage additives. A summary of 26 trials and 65 farm-scale silages. Report of Progress. Cattlemen's Day. Kansas State University, Manhattan, KS.

Ely, L.O. 1978. The use of added feedstuffs in silage production. In: Fermentation of Silage - A Review. West Des Moines, IA: National Feed Ingredient Assoc. pp. 233-280.

Hirstov, A.N., L.M. Rode, K.A. Beauchemin, and R.L. Wuerfel. 1996. Effect of a commercial enzyme preparation on barley silage in vitro and in sacco dry matter degradabilities. J. Anim. Sci. 74(Suppl. 1):296. Abstr.

Hara, S., and Y. Ohyama. 1978. Propionic acid application in preventing aerobic deterioration of silage, with references to the relationship to moisture content and additive tolerant microorganisms. Jap. J. Zootech. 49:794-801.

Huber, J. T., and M. Soejono. 1977. Organic acid treatment of high dry matter corn silage fed to lactating dairy cows. J. Dairy Sci. 59:2063-2070.

Leaver, J. D. 1975. The use of propionic acid as an additive for maize silage. J. Br. Grassld. Soc. 30:17-21.

Kung, L., Jr., J.H. Chen, E.M. Kreck, and K. Knutsen. 1993 Effect of microbial inoculants on the nutritive value of corn silage for lactating dairy cows. J. Dairy Sci. 76:3763-3770.

Kung, L. , Jr., A.C. Sheperd, A.M. Smagala, K.M. Endres, C.A. Bessett, N.K. Ranjit., J.L. Glancey. 1996. The effect of propionic acid-based additives on the fermentation and aerobic stability of corn silage and the aerobic stability of a TMR. J. Anim. Sci. 74(suppl. 1):96. Abstr.

Lewis, G.E., C.W. Hunt, W.K. Sanchez, R. Treacher, G.T. Pritchard, and P. Feng. 1996. Effect of direct-fed fibrolytic enzymes on digestion of a forage-based diet fed to beef steers. J. Anim. Sci. 74(Suppl. 1):296. Abstr.

Mann, E. M. and P. McDonald. 1976. The effect of formalin and lower volatile fatty acids on silage fermentation. J. Sci. Fd. Agric. 27:612-616.

Michal, J.J., K.A. Johnson, R.J. Treacher, C.T. Gaskin, and O. Sears. 1996. The impact of direct fed fibrolytic enzymes on the growth rate and feed efficiency of growing beef steers and heifers. J. Anim. Sci. 74(Suppl. 1):296. Abstr.

Moran, J.P., and T.R. Owen. 1994. The effects of Ecosyl treated silage on milk production by lactating cows. Proceedings from the National Conference on Forage Quality, Evaluation and Utilization. Univ. of Nebraska, Lincoln.

Moran, J.P., and T.R. Owen. 1995. The effect of feeding silage with an inoculum of Lactobacillus plantarum on beef production from growing and finishing cattle. Ann. Zootech. 44:383.

Muck, R.E. 1993. The role of silage additives in making high quality silage. Proc. National Silage Production Conference. NRAES -67. pp 106-118.

Rooke, J.A., and F. Kafilzadeh. 1994. The effect upon fermentation and nutritive value of silages produced after treatment by three different inoculants of lactic acid bacteria applied alone or in combination. Grass and Forage Sci. 49:42-53.

Sanchez, W.K., C.W. Hunt, M.A. Guy, G.T. Pritchard, B.I. Swanson, T.B. Warner, J.M. Higgins, R.J. Treacher. 1996. Effect of fibrolytic enzymes on lactational performance of dairy cows. J. Dairy Sci. 79(Suppl. 1):183.

Stokes, M.R., and S. Zheng. 1995. The use of carbohydrase enzymes as feed additives for early lactation cows. 23 Biennial Conf. on Rumen Function, Chicago, Il. p.35.

Thaysen, J. 1996. Mehr Milch oder hohere tageszunahmen durch milchsaurbakterien silagebereitung aktuell. (More milk or higher daily liveweight gain through inoculation with lactic acid bacteria) Landpost. Oct. 19. p40-41.

Treacher, R.J. and C.W. Hunt. 1996. Recent developments in feed enzymes for ruminant rations. Proc. Pacific North-West Nutr. Conf. Seattle, Oct. 7-10.

Weinberg, Z.G., and R.E. Muck. 1996. New trends and opportunities in the development and use of inoculants for silage. FEMS Microbiological Reviews. 19(1):53-68.

Woolford, M. K. 1975. Microbiological screening of straight chain fatty acids (C1-C12) as potential silage additives. J. Sci. Fd. Agric. 26:219-228.